SECTION 2. VOR AND DME/TACAN FREQUENCY ENGINEERING

1. FREQUENCY ENGINEERING.

a. Frequency channelization. VOR, Distance Measuring Equipment (DME) and Tactical Air Navigation equipment (TACAN) frequencies are listed in figure 1. The frequencies 108.00/978 MHz and 108.05/1104 MHz are specifically designated for radio navigation test generators (ramp testers) and shall not be used for operational VOR and DME/TACAN facilities.

b. Use of paired channels. The use of paired frequencies as listed in figure 1 requires that stations be collocated in accordance with one of the following:

(1) Coaxial collocation. VOR and TACAN or DME antennas are located on the same vertical axis.

(2) Offset collocation for:

(a) Standard VOR used in terminal areas for approach procedures, the separation of the VOR antenna and the associated DME or TACAN antenna shall not exceed 100¢.

(b) Doppler VOR used in terminal areas for approach procedures, the separation of the VOR antenna and the associated DME or TACAN antenna shall not exceed 260¢.

(c) Any non-terminal procedures, where the highest position-fixing accuracy of the system is required, the antenna separation limits of subparagraphs (a) and (b) apply.

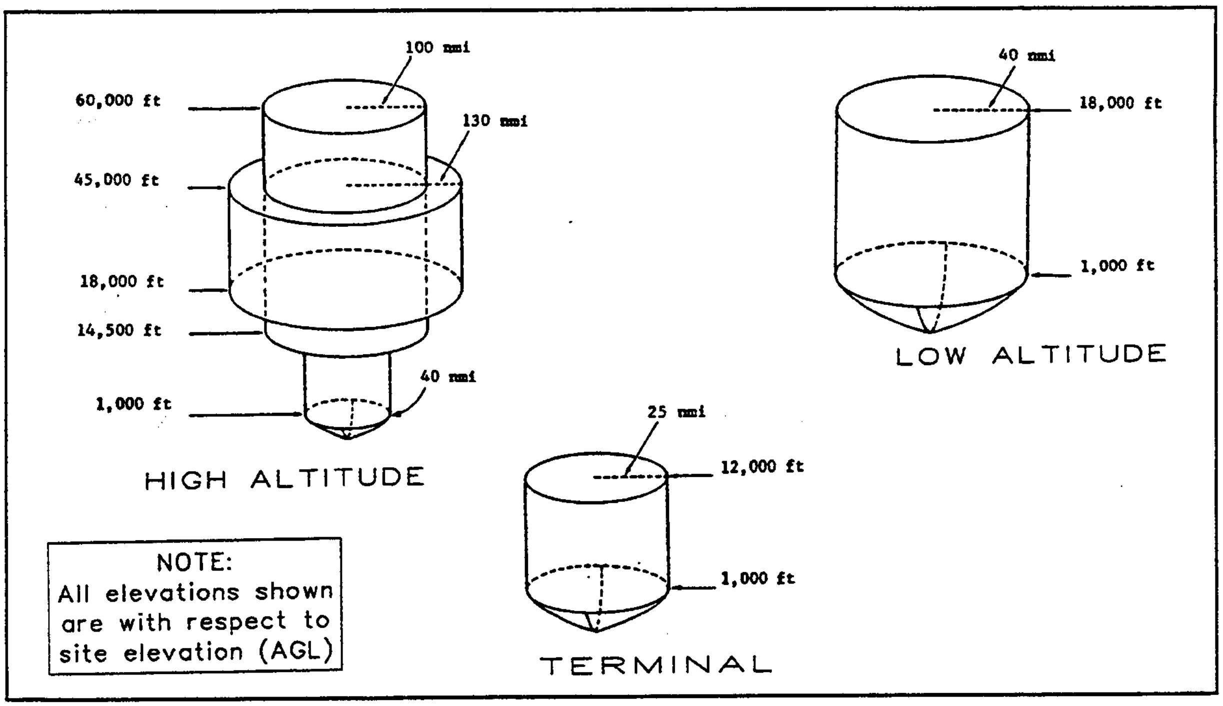
(d) For all other procedures, the separation of a VOR antenna and associated DME or TACAN antenna shall not exceed 2,000¢.

c. FPSV's. The standard circular FPSV's for Terminal (T), Low Altitude (L), and High Altitude (H) VOR-DME/TACAN are shown in figure 2. [**Note**: These are referenced to site elevation (i.e., FPSV altitudes are in AGL). Adjustments must be made if MSL elevations are needed.]

d. VOR D/U criteria. Harmful interference to VOR facilities is avoided by geographically separating cochannel and adjacent-channel assignments. Within each FPSV, the D/U ratio shall be at least the following, on a basis of 95 percent time availability

Cochannel	1st Adjacent Channel (50 kHz)	2nd Adjacent Channel (100 kHz)
+23 dB	**-4 dB Interim** **-31 dB Final**	**-43 dB**

FIGURE 2. FPSV'S FOR VOR, DME/TACAN



(1) A D/U ratio of -4 dB is necessary to assure protection of 100 kHz (100 channel) navigation receivers. This -4 dB D/U ratio is referred to as the interim criterion and shall be used whenever possible to protect 100 kHz assignments.

(2) A D/U ratio of -31 dB is for 50 kHz (200 channel) navigation receivers. This is referred to as the final criterion and shall be used for 50 kHz assignments.

(3) All the D/U ratio values include a value of +3 dB to take into account transmitter power degradation of either D or U transmitter before system shutdown.

e. DME/TACAN D/U criteria. Harmful interference to DME/TACAN facilities is prevented in the same manner as for VOR's in subparagraph d. The +3 dB factor is included and the values are:

Cochannel	1st Adjacent Channel (±1 MHz)	2nd Adjacent Channel (±2 MHz)
+11 dB	**-39 dB**	**-47 dB**

2. FREQUENCY ENGINEERING PROCEDURES. To ensure that the proposed VOR-DME/TACAN frequencies would provide interference-free operations within their FPSV's, the following analyses must be performed on the proposed frequencies:

a. Intersite analysis is used to determine whether the proposed frequencies meet the assignment criteria as specified in subparagraphs 1d and 1e. There are two analysis methods, table and calculation.

b. In addition, differences in site elevation calculations are necessary.

3. INTERSITE ANALYSIS BY THE TABLE METHOD FOR VOR. Analysis for VOR facilities may be performed on a proposed VOR frequency through the use of the following tables which show conservative/worst-case separation distances required, with respect to VOR/VOR and VOR/adjacent channel LOC:

a. Figure 3 for VOR/VOR cochannel.

b. Figure 4 for VOR/VOR 1st adjacent channel (interim).

c. Figure 5 for VOR/VOR 1st adjacent channel (final).

d. Figure 6 for VOR/VOR 2nd adjacent channel.

e. Figure 7 for VOR/LOC Undesired 1st adjacent (interim).

f. Figure 8 for VOR/LOC Undesired 1st adjacent (final).

g. Geographical separations are not required between VOR stations and between VOR and LOC stations which differ in frequency by more than 100 kHz. Therefore, there are no tables for 3rd adjacent channel VOR separations. However, facilities that differ in frequency by 150 kHz or less should not have overlapping FPSV's.

4. INTERSITE ANALYSIS BY THE TABLE METHOD FOR DME/TACAN. DME/TACAN facility analysis may be performed on a proposed DME/TACAN frequency through the use of the following tables which show conservative/worst-case separation distances:

a. Figure 9 for DME/TACAN cochannel, TACAN undesired.

b. Figure 10 for DME/TACAN 1st adjacent channel, TACAN undesired.

c. Geographical separations are not required between DME/TACAN facilities separated more than 1 channel (1 MHz). There are no tables for 2nd adjacent DME/TACAN channels.

5. DME/TACAN REQUIRED SEPARATION. In most cases, DME/TACAN facilities, separation is greater than for the frequency-paired VOR facility, en though the FPSV's for like categories (H, L and T) are equal.

a. For example, look at the VOR and DME/TACAN tables of mileage separations in figures 3 and 9. From figure 3, it can be seen that two cochannel L-VOR's of equal power require 180 nmi separation. From figure 9, two L-DMEs or L-TACAN's of equal power require 204 nmi separation. The same holds true for T-VOR and T-DME/TACAN.

b. For most power difference levels, the same is true for H-DME/TACAN, but not all.

c. DME/TACAN spaced 63 MHz. Interference may occur between DME/TACAN spaced 63 MHz apart. Reply transmissions from Channel 17Y, for instance, could interfere with interrogation signals on Channels 80X and 80Y. This can result in receiver desensitization. To preclude this problem, DME/TACAN ground stations shall not be assigned on frequencies which differ by 63 MHz unless they are separated by at least 15 nmi (28 km).

Channel	Interr. Frequency	Reply Frequency
17Y	1041 MHz	1104 MHz
80X	1104 MHz	1167 MHz
80Y	1104 MHz	1041 MHz

6. USE OF THE LARGER SEPARATION REQUIREMENT. In all cases, the larger requirement shall be used, whether it be cochannel or adjacent channel. This requires that in each VOR or DME/TACAN frequency engineering project, a determination must be made as to which has the larger mileage separation requirement, and that value used for the assignment search. This procedure is mandatory whether both of the facilities or only one of them is actually installed.

7. PERMISSIBLE USE OF TABLES. If a proposed facility meets all the requirements of all appropriate tables, the frequency request may be submitted. VOR and DME/TACAN separation are shown in figures 3 through 10.

FIGURE 3. VOR/VOR COCHANNEL SEPARATIONS

VOR DESIRED, VOR UNDESIRED
+23 dB PROTECTION

FACIL CLASS	EIRP RATIO (dB) +9	+6	+3	±0	-3	-6	-9
	(nmi)						
H-VOR	370	383	390	395	398	402	406
L-VOR	138	152	167	180	195	206	212
T-VOR	090	100	110	122	134	146	161

FIGURE 4. VOR/VOR INTERIM 1ST ADJACENT CHANNEL -50 kHz- SEPARATIONS

VOR DESIRED, VOR UNDESIRED
-4 dB PROTECTION

FACIL CLASS	EIRP RATIO (dB) +9	+6	+3	±0	-3	-6	-9
	(nmi)						
H-VOR	233	248	259	270	284	298	305
L-VOR	70	73	76	80	85	89	93
T-VOR	40	42	44	48	51	55	57

FIGURE 5. VOR/VOR FINAL 1ST ADJACENT CHANNEL -50 kHz- SEPARATIONS

FACIL CLASS	VOR DESIRED, VOR UNDESIRED -31 dB PROTECTION						
	EIRP RATIO						
(dB)	+9	+6	+3	±0	-3	-6	-9
	(nmi)						
H-VOR	143	147	152	158	175	184	195
L-VOR	44	47	50	52	54	57	61
T-VOR	32	33	34	35	36	38	39

FIGURE 6. VOR/VOR 2ND ADJACENT CHANNEL -100 KHZ- SEPARATIONS

FACIL CLASS	VOR DESIRED, VOR UNDESIRED -43 dB PROTECTION						
	EIRP RATIO						
	(nmi)						
(dB)	+9	+6	+3	±0	-3	-6	-9
H-VOR	132	135	138	140	143	146	149
L-VOR	43	44	45	46	47	48	50
T-VOR	25	25	26	26	27	28	29

FIGURE 7. VOR/LOC INTERIM 1ST ADJACENT CHANNEL -50 kHz- SEPARATIONS

VOR DESIRED, LOC UNDESIRED
-4 dB PROTECTION

FACIL CLASS	---------------EIRP RATIO----------------- (nmi)						
(dB)	+9	+6	+3	±0	-3	-6	-9
H-VOR	210	225	238	250	263	275	285
L-VOR	64	67	71	73	77	80	86
T-VOR	37	40	42	44	46	50	51

FIGURE 8. VOR/LOC FINAL 1ST ADJACENT CHANNEL -50 kHz - SEPARATIONS

VOR DESIRED, LOC UNDESIRED
-31 dB PROTECTION

FACIL CLASS	--------------EIRP RATIO----------------						
	+9	+6	+3	±0	-3	-6	-9
	(nmi)						
H-VOR	145	148	154	161	168	173	181
L-VOR	46	47	49	50	52	54	57
T-VOR	28	28	29	29	31	31	32

FIGURE 9. DME/TACAN COCHANNEL SEPARATIONS

DME/TACAN DESIRED, DME/TACAN UNDESIRED
+11 dB PROTECTION

EIRP RATIO D/U DME/TACAN dB	DISTANCE IN NMI CLASS OF DESIRED FACILITY H	L	T
+21	220	60	40
+18	260	66	45
+15	310	82	55
+12	339	102	65
+9	379	139	85
+6	385	163	98
+3	388	192	120
±0	390	204	140
-3	392	207	161
-6	394	210	164
-9	396	212	166
-12	398	214	168
-15	401	216	172
-18	406	218	172
-21	411	220	175

FIGURE 10. DME/TACAN 1ST ADJACENT CHANNEL SEPARATIONS

DME/TACAN DESIRED, TACAN UNDESIRED
-39 dB PROTECTION

EIRP RATIO D/U DME/TACAN dB	DISTANCE IN NMI CLASS OF DESIRED FACILITY H	L	T
+21 to ±0	145	45	30
-3	145	46	30
-6	148	48	30
-9	159	48	30
-12	163	50	30
-15	175	57	31
-18	194	63	31
-21	208	67	32

8. INTERSITE ANALYSIS BY THE CALCULATION METHOD. Intersite analysis may also be performed by calculating ESR and determining the required geographical separation for that ESR through the use of appropriate facility separation curves in figures 14-47.

a. ESR is an adjusted D/U ratio due to the differences in carrier power and antenna gain between two stations. It is defined as follows:

$$\boxed{ESR = D/U - P_D + P_U - A_D + A_U}$$

Where: D/U = required D/U ratio - e.g., +23 dB for cochannel VOR; -4 dB for 1st adjacent channel VOR; +11 dB for cochannel DME/TACAN, etc.

P_D = carrier power of the desired facility in dBW.

P_U = carrier power of the undesired facility in dBW.

A_D = antenna gain of the desired facility

A_U = antenna gain of the undesired facility

b. If both the desired and undesired facilities have the same carrier power and antenna gain, the ESR value would be +23 dB for cochannel VOR, +11 dB for cochannel DME/TACAN.

c. VOR and DME/TACAN antennas, in most cases, are nondirectional, so the gain is the same in all horizontal directions. However, different models of antennas have somewhat different gains which have to be taken into account as shown in subparagraph a. They are:

FIGURE 11. VOR, DME, AND TACAN ANTENNA GAIN FIGURES

	Type	Gain dBd
VOR	FA-none (Four loop)	2
	FA-none (Doppler)	2
	FA-none (4 loop)	2
	FA-none (Slot)	2
	FA-none (Dipole Array)	4
DME	FA 10153	8
	CA3167	11
	FA8974	11
	FA9639	11
	FA9783	11
	FA-none (MK3)	9
	FA-none (1020 Butler)	9
	FA-none (5351A Aerocom)	10
	FA-none (596B Wilcox)	9
	5960 (Wilcox)	8
	DB-510A	8
TACAN	FA6239/1 or /2 (TRA-2)	7
	FA6339/1 or /2 (Mod RTA-2)	9
	FA6339 (GRN-9 dipole)	6
	FA-none (YN103/4)	9

d. Using the calculated ESR value and appropriate facility separation curves, the required geographical separation (S) can be determined. Figures 14 through 20 will be used for VOR cochannel geographical separations; figures 21 through 29 for adjacent channel VOR separations; figures 30 through 38 for adjacent channel LOC separations; figures 39 through 45 for DME/TACAN cochannel separations; and figures 46 and 47 for DME/TACAN adjacent channel separations. Figures 48-60 are reserved.

e. (S) is determined as follows:

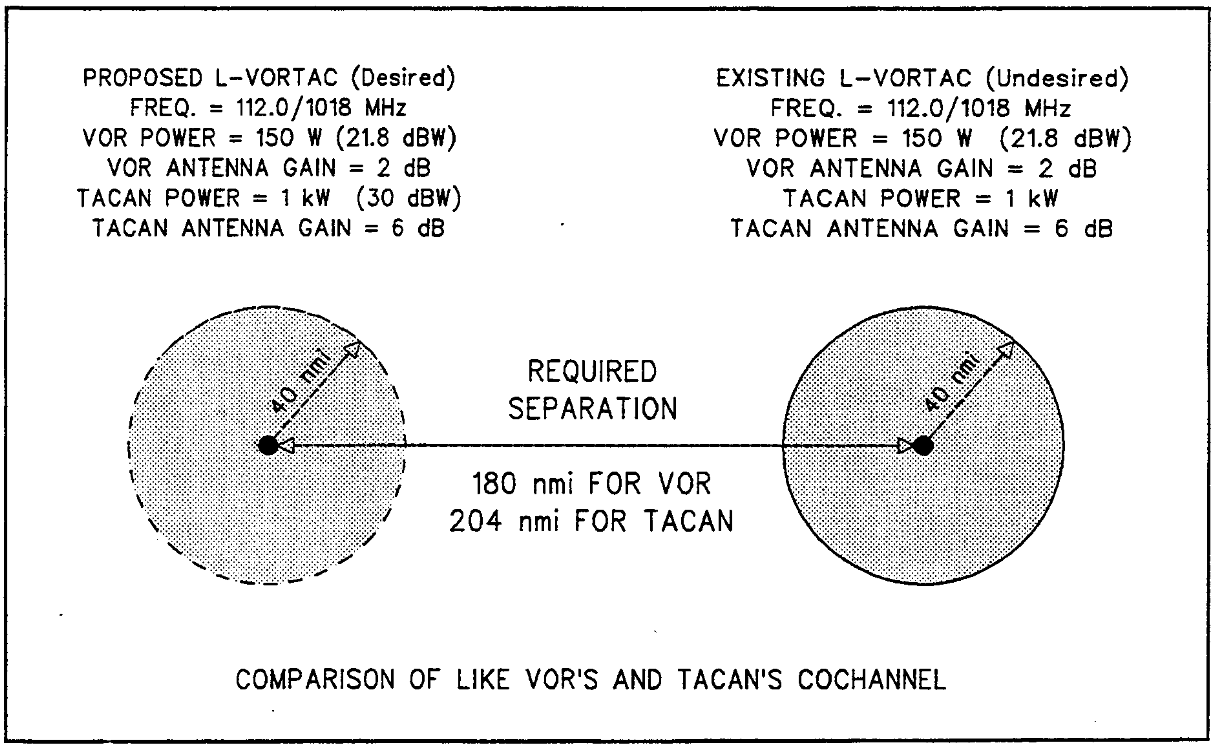
$$(S) = d_D + d_U$$

Where: d_D = the distance from the desired facility to the critical point where the intersite analysis is being made, i.e., ESV.

d_U = the distance from that point to a potential interfering facility.

9. SAMPLE OF COCHANNEL INTERSITE ANALYSIS BY THE CALCULATION METHOD.

FIGURE 12. VORTAC COCHANNEL INTERSITE ANALYSIS PLOT



a. Calculate VOR ESR as follows (see figure 14):

ESR = +23 dB - 21.8 + 21.8 - 2 + 2 = +23 dB

b. Use figure 17 (VOR facility separation curves having ESR of +23 dB) to determine (S). The distance d_D is 40 nmi and the altitude (AGL) is 18,000¢, since the FPSV of the proposed L-VOR is 40 nmi up to 18,000_. Find the point where the d_D and the altitude lines intersect. (S) for that point is 180 nmi. The required separation between the proposed VOR and the existing VOR is 180 nmi.

c. Calculate DME/TACAN ESR as follows:

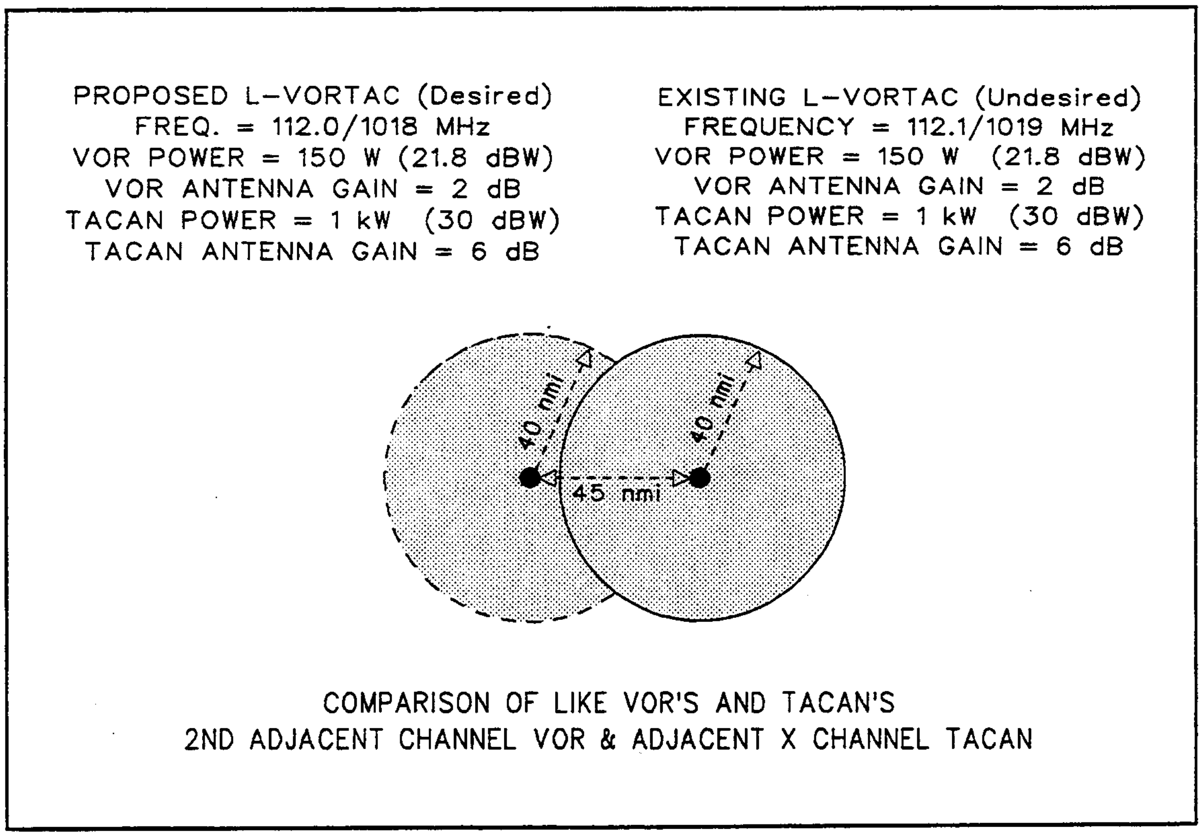
ESR = +11 dB - 30 + 30 - 6 + 6 = +11 dB

d. Use figure 44 (DME/TACAN facility separation curves having ESR of +11 dB) to determine required (S).

e. Determine the same 40 nmi and 18,000¢ intersect point. The DME/TACAN separation requirement is 204 nmi, which is the greater of the two, so this is the separation requirement.

10. INTERSITE ANALYSIS OF ADJACENT CHANNELS. This is done in a similar manner, except a different set of curves is used (see figure 13).

FIGURE 13. VORTAC 2ND ADJACENT CHANNEL INTERSITE ANALYSIS



a. Calculate VOR ESR as follows:

ESR = -43 dB - 21.8 + 21.8 - 2 + 2 = -43 dB.

b. Use figure 21 (VOR/VOR facility separation curve at 1,000_) to determine the required geographical separation. The distance d_D is 40 nmi and the ESR is -43 dB. Find the point where the d_D and the ESR lines intersect. (S) for that point is 45 nmi by interpolation. The required geographical separation between the proposed VOR and the existing VOR on the 2nd adjacent channel is thus 45 nmi. It should be pointed out that the critical point for the 2nd adjacent channel analysis is 40 nmi at 1,000_ (the lower edge of the L-VOR FPSV). For cochannel analysis, the higher edge of the FPSV, i. e., 18,000_ is the critical point.

c. Use figure 46 (DME/TACAN vs. DME/TACAN facility separation curve at 1,000¢) to determine required separation. The distance at 40 nmi and 1,000_ will be found to be 42 nmi by interpolation. The lower edge of the FPSV is used as in subparagraph b. The VOR separation requirement is the greater, so it will be used.

11. DIFFERENCES IN SITE ELEVATION. When VOR facilities differ in site elevations 1000' or more, the station separation required to protect the station with the higher site elevation must be increased as follows:

H-VOR : 3 nmi for each 1,000_ elevation difference

L-VOR : 4 nmi " " " " "

T-VOR : 7 nmi " " " " "

12. thru 13. RESERVED.